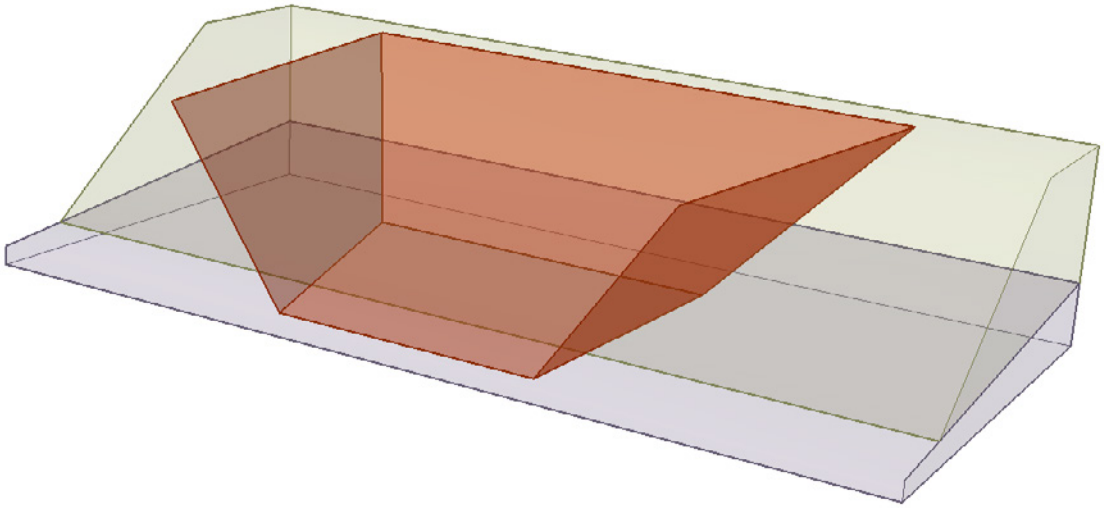
Multiplanar Slip Surface Searching for Three-Dimensional Slope Stability Analysis

Slope stability analysis often assumes the shape of the critical slip surface to be spherical or ellipsoidal. However, realistic slope failures often cannot be approximated using these simple geometries, especially in the case of planar slip surfaces, such as in slopes with anisotropic materials or plastic linings. An existing alternative practice is to utilize a series of cutting planes to delineate a 3D slip surface on a slope. *Slide*³ now features a new searching method that finds the critical slip surface by varying the locations of the cutting planes using metaheuristic global optimization algorithms such as the Cuckoo Search and Particle Swarm Optimization (PSO).

A multiplanar slip surface be defined as the slip surface formed by intersecting the upper plane space of a set of *N* planes with soil terrain. An example of a multiplanar slip surface formed over four planes is shown in the figure below.

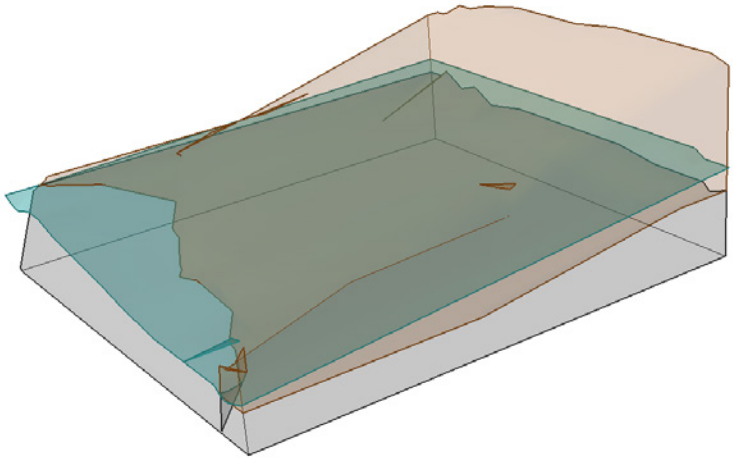


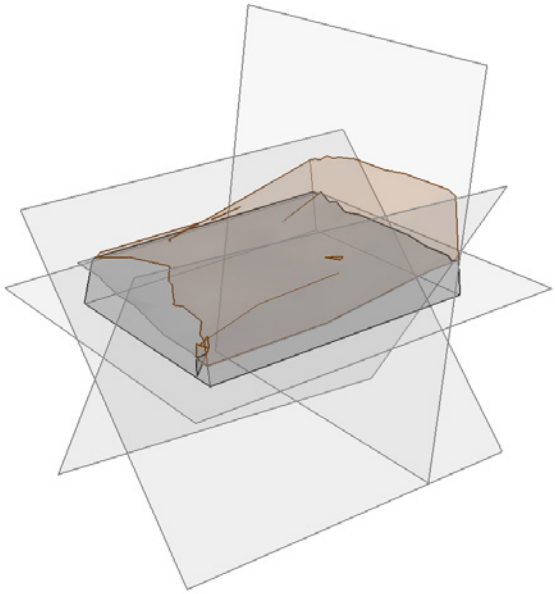
The set of planes used to form the multiplanar slip surface can each be expressed using the infinite plane equation presented below:

$$A_i x + B_i y + C_i z + D_i = 0; \quad i \in \{1,2,...,N\}$$

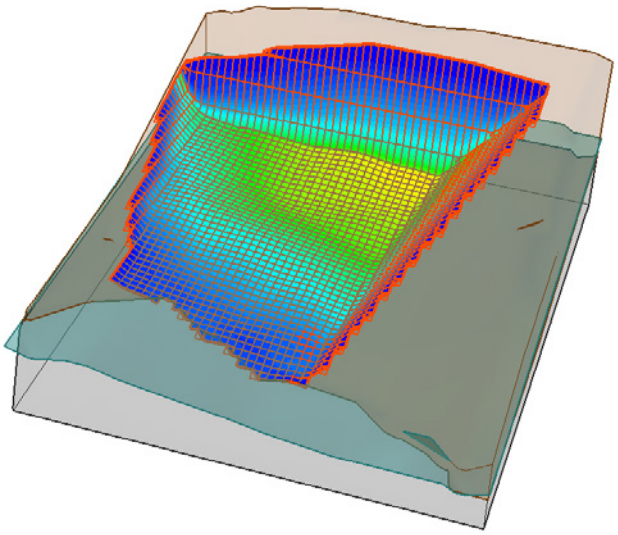
It can be seen that each of these planes can be translated by variable distances in the directions of their corresponding normal vectors to produce different slip surfaces. The process of multiplanar slip surface optimization involves varying the translations within user-specified limits to produce the minimum FOS.

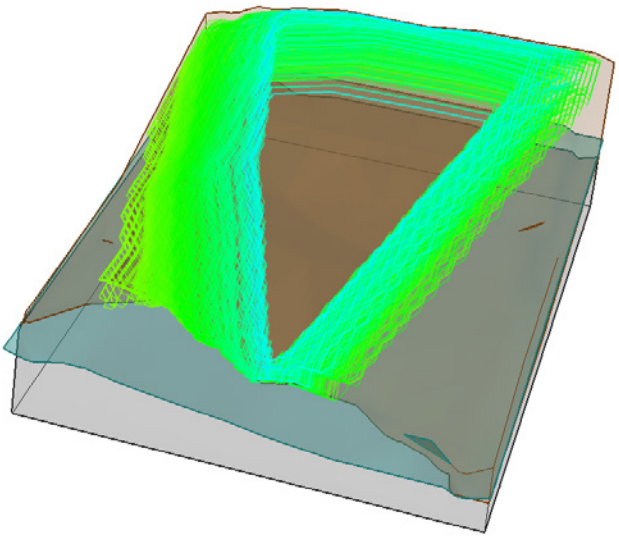
The use of multiplanar searching is applicable for planar slope failures, such as in the case of an unlined municipal solid waste (MSW) landfill. One such failure that occurred near Cincinnati, Ohio on March 9, 1996 was modeled and is presented in the figure below. The geometry and material properties of the slope were retrieved from Chugh et. al. (2007).





The top layer in the model is MSW, and the layer of leachate just before failure is shown in blue. The landfill rests on a shale bedrock, and there is a thin layer of native soil at the interface. A multiplanar search analysis was conducted on the slope using the searching planes shown in the figure above. Note that the weak native soil layer interface was also used to cut the slip surfaces to create composite slip surfaces. By varying the locations planes in the Cuckoo Search, the critical slip surface was determined and shown in the left figure below.





The right figure above shows the range of slip surfaces that were generated and analyzed in the search. This model demonstrates the utility of multiplanar searching in predicting the critical slip surfaces of slopes that commonly experience planar failures.

Another use of multiplanar searching is when planes of anisotropy are present in the model. The new feature allows planes to be specified in the direction of anisotropy. Tutorial 16 in Slide[3] guides the user on how to use this new feature.

Reference:

Chugh, A.K., Stark, T.D., DeJong, K.A. (2007). Reanalysis of a municipal landfill slope failure near Cincinnati, Ohio, USA. *Can. Geotech. J.* vol. 44, pp. 33-53.